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AIRPLANE WING FITTINGS

(AIRPLANE SECTION, S. & A. BRANCH)

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Prepared by R. A. Miller
Engineering Division, Air Service
McCook Field, Dayton, Ohio
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AIRPLANE WING FITTINGS.

INTRODUCTION.

It is the intention in this report to discuss the various wing fittings that are in use at the present time, pointing out the good and bad features of each. No attempt will be made to recommend or to design a standard set of fittings, as, at the present stage of airplane development, the variety of designs, truss arrangements, spar shapes, and materials is too great. Likewise, the scope of this discussion will be confined to fittings in use on wood spars, as it is felt that there has not been sufficient time and opportunity to make much progress in developing metal construction. However, a great deal of this discussion applies to wing fittings with metal spars as well as with wood spars.

GENERAL PROPERTIES.

The function of wing fittings is to connect the various structural members together so as to hold them firmly in their true relation to each other and to transfer and distribute the various stresses. A properly designed fitting should have the necessary strength, a minimum of weight, and as uniform a distribution of material as possible. It should be compact and rigid, and develop no serious eccentricities. The fitting should be so designed that it is easily assembled on the airplane, is easily replaced, and can be rapidly and economically produced.

It is quite obvious that the fitting should have the requisite strength with the least weight possible. The fitting should be strong enough to develop the full strength of all structural members attached to it. At the same time the fitting should be well proportioned, so that its strength throughout will be as nearly uniform as possible.

It is very difficult to eliminate all eccentric stresses from a fitting and yet have a fitting that is light in weight, easy to manufacture, and easy to assemble on the airplane. Poor design might easily result in eccentric stresses that would be more severe than the primary stresses resulting from flying or landing conditions. It might be well to point out that an eccentricity that decreases the moment at the strut point will increase the moment in the span, and an eccentricity that decreases the moment in the span will increase the moment at the strut. Great care should be exercised in the design, so that any eccentric stresses that may result will be so small as to be negligible.

The fitting should be sufficiently strong and rigid so that the position of no part of it can be changed by the loads that may come upon the structure. This is especially true of drag-truss fittings, as, once the airplane is completed it is impossible to inspect them without removing the fabric from the wings. If a fitting should bend, twist, or give, it might throw the structure out of line, resulting, perhaps, in a decrease in the performance of the airplane, excessive stress in some member, or even in the destruction of the airplane. The fitting should be as compact as possible, so as not to interfere with the other parts of the airplane and, in the case of external fittings, so as to cause as little wind resistance in flight as possible.

A fitting might be quite economical as to material, have sufficient strength, and yet be a very poor production job. An assembly of thin and thick pieces, or poor arrangement of lightening holes, might result in a fitting that would be exceedingly difficult to braze, weld, or heat-treat successfully. Material should be used that is readily obtained and the fitting should be so designed that it may be quickly and easily manufactured.

Ease of assembly on the airplane and ease of replacement are also important, and the fitting should be designed so that it may be assembled in position on the airplane or replaced with a minimum of disturbance of the other parts of the structure.

The best method of attaching metal fittings to a wood spar is by means of bolts. Wood screws do not give as rigid and positive a connection, and rivets should never be used, as driving the rivets tends to enlarge the hole and thus to weaken the spar. The fittings should never be attached to the spar by vertical bolts through the spar, as vertical holes in the spar weaken it materially through loss of area and reduction of the moment of inertia in the plane of the greatest bending moments. Vertical bolts that straddle the spar should be used or horizontal bolts through the spar near its neutral axis. The use of horizontal bolts is very satisfactory, as a fitting of this type usually has no eccentricities, and if the bolts are kept close to the neutral axis the holes have little effect upon the strength of the spar.

BRAZING AND WELDING.

When a permanent joint is made in assembling a wing fitting the pieces should be brazed together. A weld will transmit compressive stresses successfully and is a satisfactory method to use at the ends of struts when the material is low-carbon steel. But a weld can not be depended upon to take tension and should never be used when it will be subjected to heavy bending or tensile stresses. High-carbon, alloy, or heat-treated steels should never be welded, as welding reduces their strength considerably. Subsequent heat treatment will not help materially, as the excessive temperature of the welding operation has burned more or less of the carbon out of the steel. Brazing heat-treated steels somewhat reduces their ultimate strength, and fittings of heat-treated steels should be subjected to heat treatment after the brazing operation in order to bring out the full strength of the material. Heat treatment is feasible if a spelter with a sufficiently high melting point has been used in the brazing operation. Wing fittings should not be soldered, as the strength of soldered joints is very low and the joints are not dependable. However, splices in steel wire cables should be soldered and plugs in the ends of metal struts may be riveted and soldered.

SPAR FITTINGS.

Wing fittings may be divided into three general groups—interplane fittings, internal or drag-truss fittings, and couplings to attach the wings to the fuselage or center section. The first group includes the connection between the interplane struts, the lift and landing wires, the incidence wires, and the spars. Various combinations of bolts with suitable heads, lug plates, sockets, yokes, and box fittings are used to tie these members together and to insure a firm and rigid connection between them and the spar. These combinations fall into four general types, and the numerous designs differ from these general types only in minor details.

The earlier practice in airplane design was to attach the interplane members to the spars by means of vertical bolts through the spars. In some designs the wires and struts were attached directly to the bolts, but more often they were attached to lug plates which were bolted to the spars. Attaching a flying wire directly to a vertical bolt in the spar causes a bending moment in the bolt, creates a serious eccentric moment in the spar, and transfers the vibratory stresses in the wire directly to the fiber of the spar adjacent to the bolt. This, of course, is very unsatisfactory. Attaching the wires to lug plates which are bolted to the spars by vertical bolts through the spars decreases the eccentric stresses in most cases and reduces the effect on the spar of the vibratory stresses from the wires. Fittings consisting of vertical bolts in the spar and washers or lug plates are light in weight, are easily assembled, and are easy to replace; but they materially reduce the strength of the spar.

The Vought VE–7, the DH–4, and the Pomilio airplanes furnish good examples of this type of fitting. In the Vought VE–7 the interplane members are fastened to a lug plate which is attached to the spar by two vertical bolts through the spar. The DH–4 design is slightly modified, as the incidence and lift wires are attached to a lug plate which is fastened to the spar by two vertical bolts in the spar, one of which has a forked head to receive the interplane strut, and by a third bolt which passes through a wood piece that is glued and taped to the inner side of the spar. This arrangement is shown in Figures 1 and 2. The Pomilio wing fitting (figs. 3 and 4) is worthy of note, as a good example of poor design. The designer placed a box fitting on the spar and then attached the wires and strut to the spar by means of a lug plate fastened to the spar by means of vertical bolts in the spar. The metal in this box fitting, excepting that portion which is immediately adjacent to the bolts, serves no purpose but to add weight to the wings.

The second general type includes the designs in which the fitting bolts are vertical and straddle the spar. Tie-plates or lug plates on both flanges act as bolt spacers and assist in distributing the loads. Good examples of this type of fitting are found on the Curtiss JN–4 (fig. 5) and the Orenco airplanes (figs. 6 and 7). It will be observed that wood pieces are glued, bolted, and sometimes taped to the sides of the spar, and the lug plates to which are attached the wires and struts are fastened to the spar by means of the vertical bolts in these wood pieces. The glue should not be depended upon too much, and horizontal bolts should be used to prevent the wood pieces from sliding along the spar. These horizontal bolts may also be used to carry the drag-truss lug plates. This type of fitting is light, easily assembled on the airplane, and is easy to replace. Care should be used in the design, more particularly with the thicker wing sections, so that any eccentricities developed will be so small as to be negligible.

A modification of this type is found on the Lepere U. S. A. C–11. In this design wood blocks were not used. The four vertical bolts which fix the picture-frame struts straddle the spar and the inner pair of bolts straddle the drag-strut fitting, being spaced by the strut plates at one spar flange and by a tie-plate at the other. The lift wire-lug plate has side pieces which lie across the sides of the spar to which it is fastened by two horizontal bolts which also carry the drag strut and wire fittings. In this design the safety factor is not so high as in the design with the wood pieces, and it is somewhat heavier. However, it is more easily installed and has given very satisfatory service. A sketch of the Lepere fitting will be found in Figure 23.

A minor advantage of the types of fittings using lug plates with vertical bolts is that the fabric may be placed on the wing more easily, as there will be no interference from projecting parts of the fitting.

The box fitting will be considered as the third general type. Designs of this type take the form of a box or sleeve which must be slid along the spar into position. It is extremely difficult to get a firm, tight fit, and if the spar is not tapered wood spacers must be used. It would be impossible to replace a fitting of this type without removing the fabric, ribs, and drag members of the wing. The wires and struts are attached to lugs which are brazed to the metal sleeve or formed in the extended sides of the fitting. The fitting should be fixed in position on the spar by horizontal bolts which may be also used to carry the drag strut and wire lug plates. This type of fitting is especially efficient in distributing the stresses coming into the spar, and it transfers stresses between interplane members and drag members largely through the metal fitting instead of through the spar. This type of fitting is somewhat heavy, difficult to assemble on the spar, and a great deal of trouble to replace. However, careful design should eliminate all serious eccentricities when a box fitting is used. Examples of this type of fitting are to be found on the Nieuport 27, the Salmson 2A2, and the GA–1.

A modification of this type of fitting will be found on the TW–1. (See figs. 8 and 9.) The box fitting is made in two pieces—a yoke that fits over the spar and a cover or tie-plate. Two vertical bolts, to which are attached the interplane struts, straddle the spar, passing through the cover plate, the flanges formed in the yoke, and through a plate brazed to the top of the yoke. The cover plate has lugs formed in it to which are attached the lift wires. Horizontal bolts fix the fitting in place on the spar. This fitting is easily assembled on the spar and would be very easy to replace. But it is a little heavier than a box fitting made in one piece, and because of the way the lift wires are attached to the spar by the two vertical bolts it develops serious eccentricities. This eccentricity is large enough so that the moment induced in the fitting caused crushing of the spar at the outer end of the fitting. In the effort to prevent the spar from crushing, this fitting was redesigned for the CO–2 and the fitting extended along

the spar until we have the extremely heavy fitting shown in Figure 10. However, the bolt arrangement remains the same, and in this particular case the eccentricity is large enough to reduce the safety factor of the spars by 15 per cent.

In the fourth general type the stresses in the struts and wires are transferred to the spars by means of horizontal bolts in the spars. A good example of this type of construction is to be found in the Thomas-Morse MB-6; a photograph of this fitting will be found in Figure 11. A horizontal bolt at the neutral axis of the spar carries lugs for the flying wires and has an eye-forked head for the drag-strut connection. This bolt passes through plates on the sides of the spar which extend along the spar and are fastened to it by means of six additional bolts or rivets. Rivets are used in each case at all holes but the two at which there are bolts to receive the drag-wire lugs. The plates help somewhat in distributing the stresses in the spar due to the concentrated loads from the wires and struts. The interplane strut socket has pieces that straddle the spar and eyes formed in them fit over the horizontal bolt. This fitting is light in weight, is easily assembled on the spar, would be easily replaced, and eliminates all serious eccentric stresses except in reversed flight. As there is but one landing wire which is attached at one end of the horizontal bolt, a considerable eccentric moment is developed in reversed flight in the direction of the least moment of inertia of the spar. The use of rivets is a bad feature, as driving the rivets tends to enlarge the holes and thus to weaken the spar.

The Orenco PW-3 fitting (fig. 12), and the Dayton-Wright TA-3 fitting (fig. 13), furnish additional examples of this type of design. It is recommended that when the wires are attached to one horizontal bolt, which must transmit the entire load to the spar, plates with additional small bolts be used, so as to avoid extreme concentrations of stress on the wood fiber. This is especially important in thick wing sections with thin spars. The GA-1 fitting (fig. 14) is a good example in that respect, though the wing section is not especially thick. The fitting is well designed so that there are no eccentricities, and a number of small bolts tend to distribute the stresses in the spar. In using bolts in this manner, the designer should make certain that the bolts are placed as far from the flanges of the spar as possible. These fittings are very light, easily assembled, and are easily replaced.

The fittings on the TP-1, an airplane being designed at McCook Field, are excellent examples of this type of construction. Sketches of them will be found in Figures 24 and 25. The fittings are light in weight, easily installed or replaced, and have no eccentricities. The horizontal bolts are arranged so as to distribute the stresses in the spar, and straps over the top of the spar relieve the bearing stresses of the bolts on the spar fiber.

The fitting on the Loening monoplane, shown in Figures 18 and 19, is a modification of this type. Plates bolted to the sides of the spar extend over the upper flange in the form of a yoke and have extensions on the lower side of the wing, in which eyes are formed to receive the hinge pin of the strut connection. This design would be very satisfactory if the bolts were not placed so near the flanges of the spar and were more uniformly distributed. The U-shaped or strap fitting as used on the Fokker D-7 and the PW-1A is shown in Figures 15, 16, and 17. It will be observed that the horizontal bolts are kept well away from the flanges. These fittings are very light, easily made, and easily placed in position on the spar.

STRUT FITTINGS.

There has been a great variety of interplane strut fittings, though most of them are of the ball-and-socket or hinged types, differing only in minor details. In general these types are very satisfactory, as they are light in weight and are easily assembled or disassembled. As a rule, the pin should be parallel to the spar, as this gives the greatest degree of fixity of the strut ends in the direction of the least moment of inertia of the strut. (See fig. 20.) With the pin parallel to the spar it is possible to change the stagger of the wings readily, which is an advantage in experimental work, or where a new design is being brought out. In airplanes with internally braced wings or with continuous spars the interplane struts may carry either compressive or tensile stresses, and the fittings should be designed accordingly. This is also true of the lift struts on monoplanes and of the cabane or center section struts on most airplanes.

The fitting is generally attached to wood struts by means of a socket or shoe which fits the end of the strut and is held in place by a pin, a bolt, or by wood screws. Figures 1, 2, 5, 7, and 11 illustrate this type of connection, which is light, easily installed, and has proven to be very satisfactory. The arrangement shown in Figure 12 does not distribute the stresses throughout the material at the ends of the strut and tends to split the strut. In the case of metal struts either a socket or a plug may be used. Plugs should be riveted and brazed to the strut, but in many cases it is satisfactory to weld the sockets in place or even to rivet and solder them. The plug or socket has a suitable recess or head to complete the connection with the spar fitting. This may be a socket to fit over an eye, fork, or ball head on a bolt or plate, or an eye to complete a hinge joint, or a ball to complete a ball-and-socket joint. Some of the different methods are shown in Figures 6, 9, 13, 15, 19, and 20.

When the strut connection is made to a suitable head brazed to a lug plate which is bolted to the spar, as shown in Figure 6, or to a strap fitting which slips over the spar, as shown in Figures 12, 15, and 17, careful design will prevent any serious eccentricities. If the interplane struts slant so as to form an acute angle with the longitudinal axis of the spar, the strut fitting may be arranged as shown in Figure 13, so as to prevent serious eccentric stresses. On the DH-4 and the TW-1 the struts were attached directly to the bolts as shown in Figures 1, 2, and 9. The DH-4 arrangement was faulty, inasmuch as the bolt passed vertically through the spar. Otherwise this method is as satisfactory as the one in which the attachment is to a head brazed onto a plate. However, in most cases it is easier to prevent eccentricities when plates are used.

When the spar fitting is of the box type, the side pieces may be extended beyond the spar and formed into lugs, or lugs may be brazed to the sides of the fitting. A pin through these lugs, together with a suitable fitting on the strut, completes the connection. The GA-1 furnishes a good example of this type of construction. The connec-

tion is light and easily made, but it would be more satisfactory if the lugs were brazed to the fitting so that the pin would be parallel to the spar.

In the Thomas-Morse MB-3 and MB-6 the strut socket has side pieces that straddle the spar and are attached to it by means of a horizontal bolt, as shown in Figure 11. This arrangement is light, does not cause eccentric stresses, and is easily installed. However, it is not as readily disassembled as some of the other types, the least degree of fixity is in the direction of the least moment of inertia of the strut, and the strut length is increased.

A more rigid type of connection was used on the Salmson 2A2 and the Lepere U. S. A. C-11. The Salmson 2A2 fitting consists of a socket brazed to a box-spar fitting, into which the end of the wood strut is fitted. The end of the strut is tapered to such an extent that the degree of fixity is not materially increased beyond a coefficient of 1, and the fitting is of a type that is not easily assembled or replaced on the spar. For the Lepere connection steel plates bent into the form of a J are bolted to the sides of the picture-frame strut. Vertical bolts through these pieces straddle the spar and are held in place by a tie-plate on the opposite flange of the spar and by the drag-strut fitting. This arrangement is light, gives a good degree of fixity, and is easily installed or replaced. A sketch of the Lepere strut fitting will be found in Figure 23.

Considerable work has been done on designs for adjustable interplane struts and one or two excellent designs have been completed. Adjustable struts have many desirable features when installed on experimental airplanes, but they are heavier and more difficult to construct and there is no apparent reason why they should be used on standard designs.

LIFT WIRES.

Standard stream-lined wire or steel-wire cable is generally used for the flying and landing wires. The stream-lined wires are attached to the lugs by means of universal ends which consist of a clevis and trunnion, as shown in Figures 1, 11, and 12. The clevis fits over the lug to which it is secured by a pin or bolt, and the trunnion receives the threaded end of the wire, which is fixed in position by a lock nut. Or the clevis may be formed into a lug itself, as on the Thomas-Morse MB-6 (fig. 11). The wires should never be secured at the ends, as shown in Figure 20, as the universal ends are necessary to allow for the vibration of the wings. The wire cables are attached to a lug at one end by means of a clevis and to a turnbuckle at the other. This permits the tension in the wires to be adjusted easily. The cable is bent over a thimble and spliced to form an eye in the end. The eye is attached to the lug by means of a clevis or the eye is spliced to include the adjustable end of the turnbuckle. The splice should be wrapped with fine wire and soldered. Cable connections are shown in Figures 2, 3, 5, 6, 7, and 13. Stream-lined wire is much more satisfactory than steel-wire cable, as it will not stretch, is easier to install, and has considerably less wind resistance. However, steel-wire cable has a certain advantage in ease of manufacture, as the stream-lined wires must be made special for each length required, while the cables can be cut and spliced to suit.

The flying and landing wires are attached to the spar by means of bolts in the spar, by means of lugs formed in lug plates, or by means of lugs brazed to box or strap fittings. The fitting should be designed to develop the full strength of the wire without failure. Care should be exercised in the design to eliminate wind resistance and eccentricities. A small eccentricity in a wire connection might easily cause a moment great enough to decrease the safety factor of the spar as much as 15 or 20 per cent.

The Thomas-Morse MB-6 (fig. 11) furnishes a good example of the design with the wires attached directly to a horizontal bolt in the spar. As the bolt is at the neutral axis of the spar and on line with the interplane strut, no eccentricity is developed. However, in reversed flight considerable eccentricity is developed in the direction of the least moment of inertia of the spar, due to the fact that there is but one landing wire in each bay of each truss and that it is attached to but one end of the horizontal bolt. Otherwise this design is very good. Other good examples of this type of design will be found on the Orenco PW-3, shown in Figure 12, on the Dayton-Wright TA-3, shown in Figure 13, and on the TP-1, Figure 24. The flying or landing wires should not be attached directly to the ends of vertical bolts, as this arrangement will generally cause serious eccentricities in the spar.

When lugs are brazed to a box fitting or formed in the extended sides of the fitting, as shown in the Salmson 2A2 or the GA-1, it is easy to arrange them so that the wire tensions will not cause eccentricities. This type of fitting is satisfactory in many ways, though it is heavier than many of the other types and is rather difficult to install on the spar. Figure 14 shows a wire fitting for one of the intermediate wing spars of the GA-1. It is light, easily made, readily replaced, and would have no serious eccentricities unless the wings had considerable stagger.

More often the wires are attached to the spars by means of lug plates which are bolted to the spar. A lug plate is a piece of sheet metal which is bent up at the ends to form eyes or lugs. The plate may be attached to the spar by vertical bolts in the spar as on the Vought VE-7 and the DH-4, or it may be attached by means of vertical bolts that straddle the spar as on the Lepere, the Curtiss JN-4, and the Orenco C and D. Using vertical bolts in the spar weakens it materially. Figures 1, 2, and 3 show this method of attachment. The use of lug plates with bolts that straddle the spar, as shown in Figures 5, 6, and 7, is generally quite satisfactory, as this type of fitting is light in weight, easily made, and is easily installed or replaced on the wings. Furthermore, careful design should eliminate all serious eccentricities, though the use of two bolts, as shown in Figure 9, will generally increase them. Figure 21 illustrates the results of a failure due to eccentric stresses. The flying wires were attached to the lower bolts in the compression rib and the eccentric moment set up about the longitudinal axis of the rib caused failure of the rib fitting.

INCIDENCE WIRES.

Incidence wires are generally fastened to the spars by means of lug plates or to the interplane strut socket by means of lugs or posts brazed onto the metal end piece or formed in it. These methods are shown in Figures

1, 2, 3, 5, 6, 7, 11, and 20. When attached to the strut socket, eccentricities may be induced, but they will be small and are in the direction of the greatest moment of inertia of the strut. In general these types are light in weight, easily assembled, and are satisfactory in every way.

In some instances the incidence wires have been attached directly to an eyebolt which acts as one of the spar fitting bolts. This arrangement was used on the XB-1A and is satisfactory when the spar fitting has but two vertical bolts which are in the line of the interplane struts.

In the Vought VE-7 the incidence wires are attached to a lug plate which is let into the strut itself, splitting the strut at one end along the major axis of its cross section, and pin connected to the strut and strut socket. This type of construction is not so desirable, as it weakens the strut somewhat and is more difficult to manufacture.

INTERNAL DRAG STRUTS.

Compression ribs or drag struts made of wood are generally attached to the spars by running the cap strips over the spars and fastening them to the spars by means of glue and nails. The end of the rib is glued to the sides of the spar and the joint is strengthened by triangular blocks glued and nailed to the rib and to the spar. This method gives an extremely light joint and is satisfactory in every way. However, care should be exercised so that the strut will have an even, firm seat on the spar. This type of drag strut and its end connection is shown in Figures 2 and 19. When the wood drag strut does not also act as a former rib it may be bolted to the drag-wire lug plate, as shown in Figures 6 and 24. This type of strut is easily built, the end connections are simple and easily made and installed, and the ultimate strength of the strut can be computed with considerably more exactness than the built-up type of strut shown in Figure 2.

Metal struts are generally made with plugs in the ends which are bolted to suitable fork or eye heads on a horizontal bolt through the spar or on a plate which is bolted to the spar. If a plate is used, a suitable head is brazed to the plate and the ends of the plate are turned up and formed into lugs which receive the drag wires. These types are shown in Figures 3, 8, 11, and 22. They give a light, firm joint, which is quite essential for drag truss members, as they can not be inspected once the wing is completed without removing the fabric. However, the degree of fixity of the strut ends is very low. The arrangement of the drag-strut connections on the CO-2 is much more satisfactory in this respect, as angles are riveted to the tubes or metal boxes which are used as struts and then bolted to the spars. This gives a much better degree of fixity and a lighter strut may be used. The horizontal bolts through the spar should be placed close together so as to weaken the spar as little as possible.

A special case is furnished by the VCP-1. (See fig. 21.) The compression rib at the outer strut is attached to the spars by means of a piece of sheet metal bent to form a yoke that fits over the rib and is bolted to it and with the ends bent up to form angles which are bolted to the spars. This gives a rather heavy fitting, but the degree of fixity of the strut ends is high and the heavy fitting is necessary because the I-strut is attached to the center of the compression rib between the spars, and the rib must carry heavy bending loads as well as compressive stresses.

INTERNAL DRAG WIRES.

The drag wires are attached either to lugs which are brazed to box spar fittings or to lug plates which are bolted to the sides of the spar by two or more bolts. The bolts should be placed at or near the neutral axis of the spar so as to effect its moment of inertia as little as possible. On the outer side of the spar a good-sized washer or plate should be used with the bolts, as shown in Figure 22, so as to prevent crushing of the wood. These types give light, firm joints and are satisfactory in every way.

In the older designs steel wire was used for the drag wires. A turnbuckle was placed at one end for ease in adjustment of the initial tension in the wire and the joint was accomplished by threading the wire through the eye or lug and serving it, as shown in Figures 5, 6, 7, and 19. In the more modern designs swaged tie-rods are used, as they will not stretch as easily as the steel wire, which is quite important for drag-truss members. The tie-rods are connected to the lugs by means of clevis ends, as shown in Figures 2, 8, 9, 11, 21, and 22.

WING COUPLINGS.

Where wings are hinged at the fuselage or center section, a hinge coupling with the pin horizontal is the best arrangement, as it allows changes in the dihedral angle, does not interfere with the deflection of the wings, and is easy to mount or dismount. The fitting should consist of a shoe which fits over the end of the spar and is bolted to the spar by means of horizontal bolts. Vertical bolts weaken the spar considerably and should not be used. Suitable eyes are brazed onto the ends of the shoe which, together with the pin, complete the joint.

When a vertical pin is used to complete the connection, the fitting transmits more or less bending to the longerons or to other parts of the structure. As it is impossible to determine the amount of bending carried by the fitting in this case, it is impossible to make an exact analysis of the bending moments and stresses in the spars and adjacent structural members, because the spar is neither hinged nor continuous. When a horizontal pin is used, the spar is pin jointed at this point beyond question and the bending moments, shears, etc., in the spars may be determined with precision.

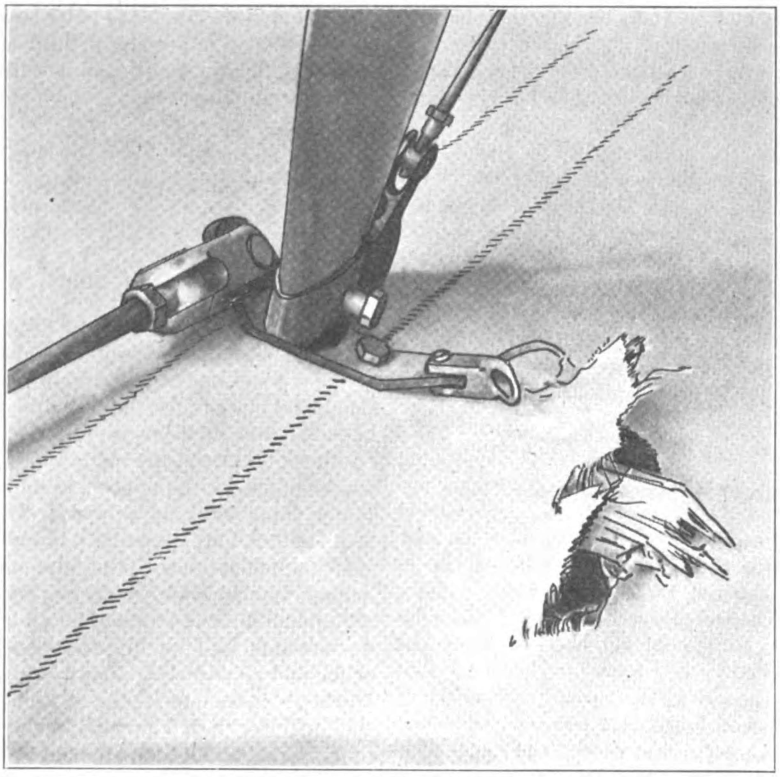

Fig. 1.—DH-9A.

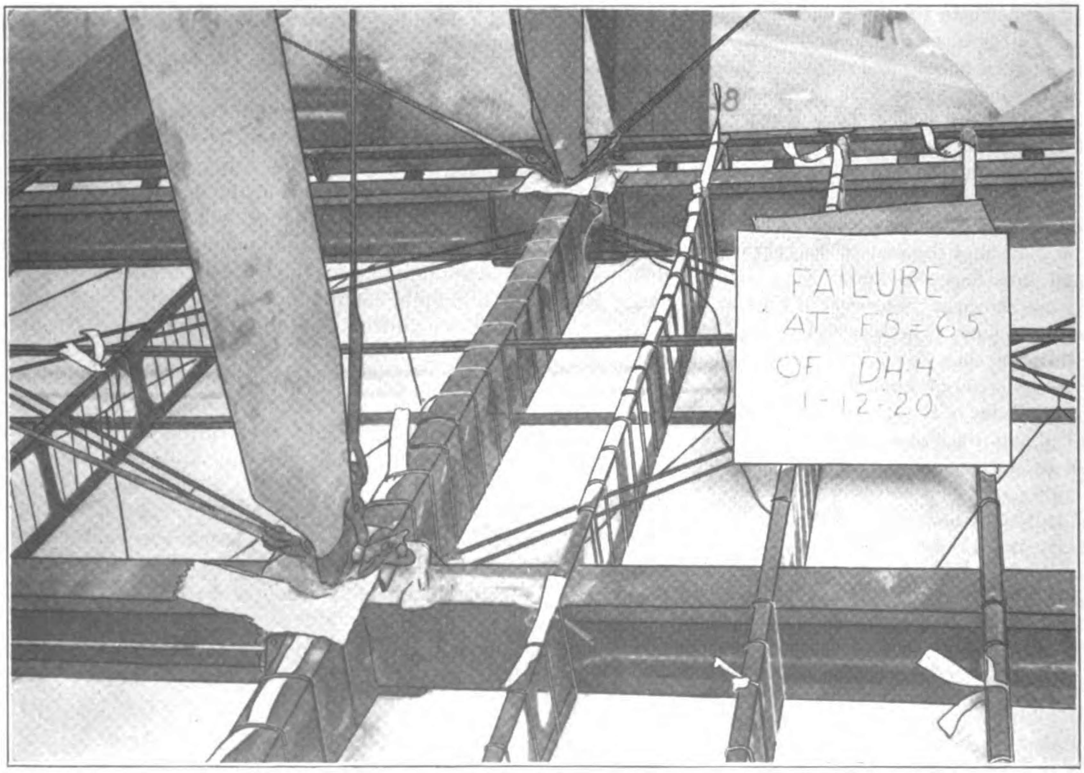

Fig. 2.—DH-4.

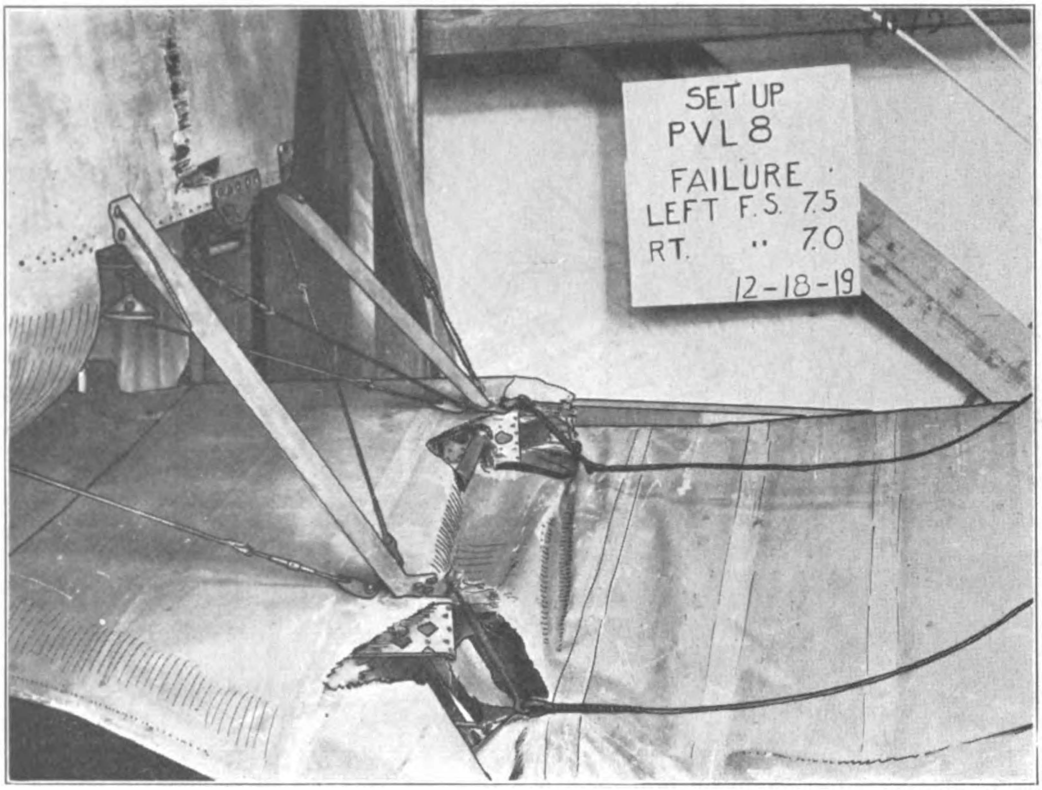

FIG. 3.—Pomilio FVL-8.

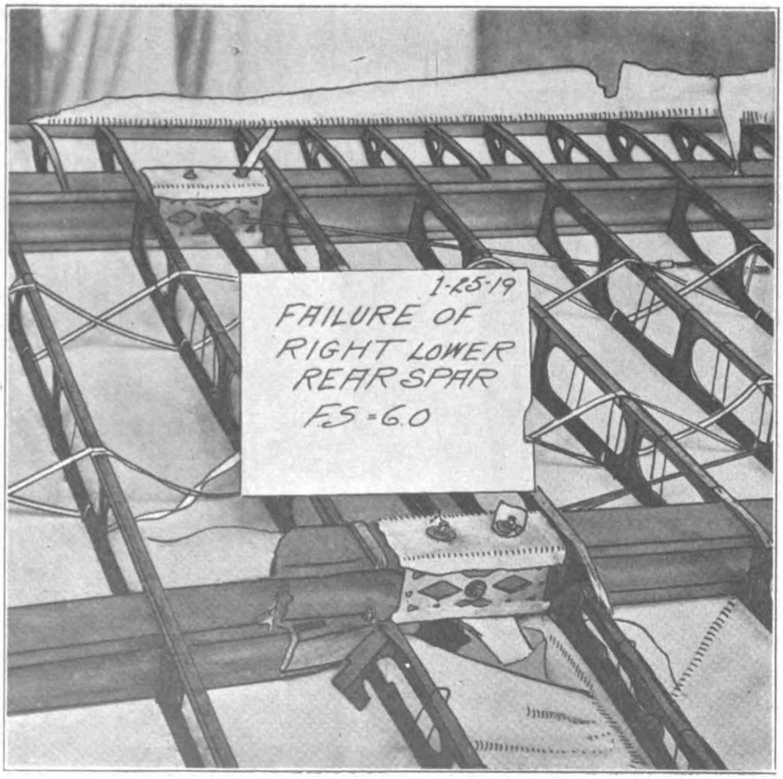

FIG. 4.—Pomilio BVL-12.

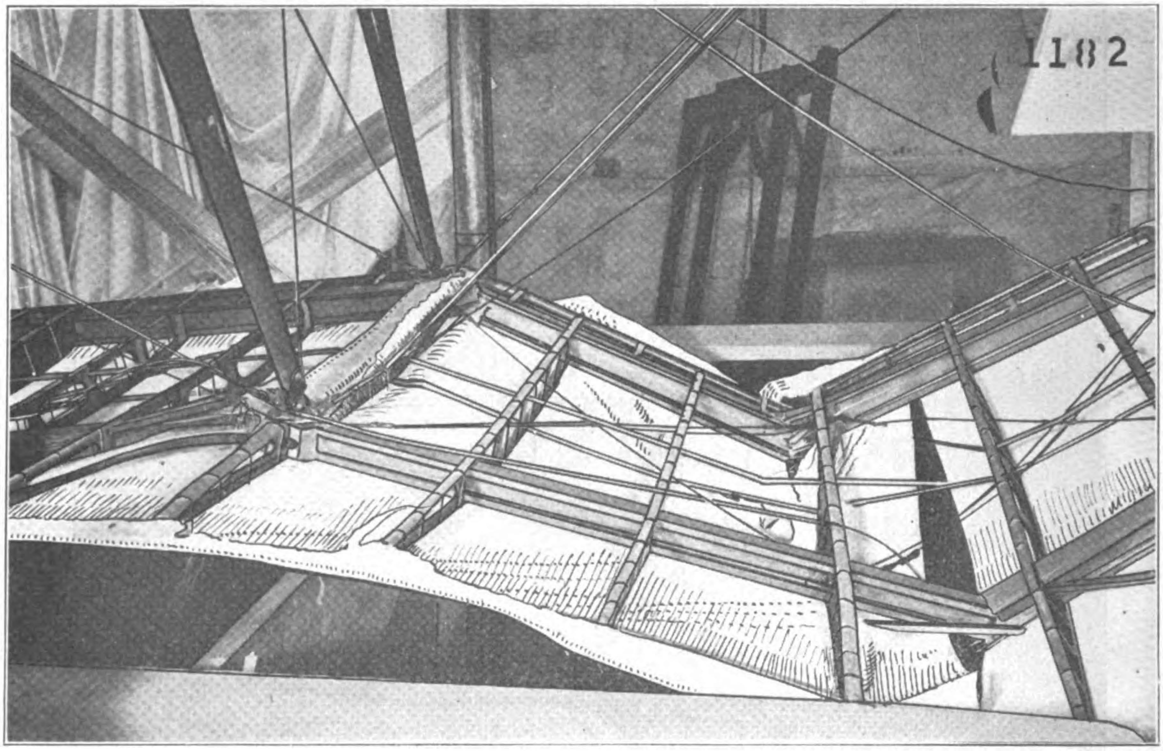

FIG. 5.—JN-4.

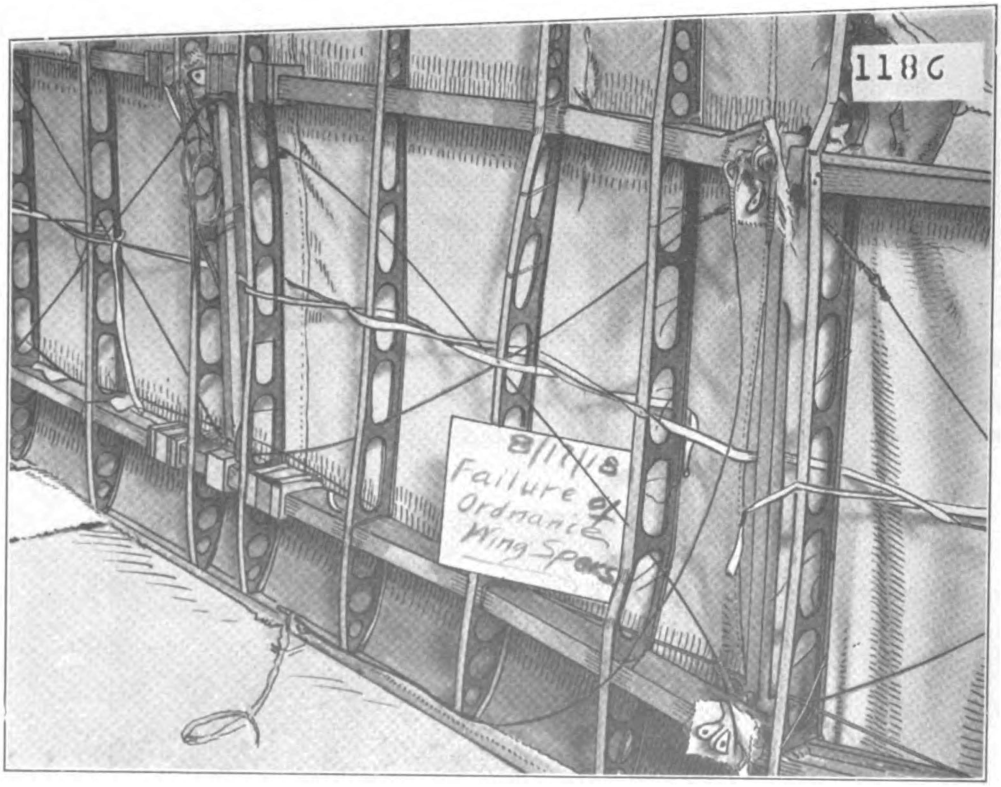

FIG. 6. Orenco-C.

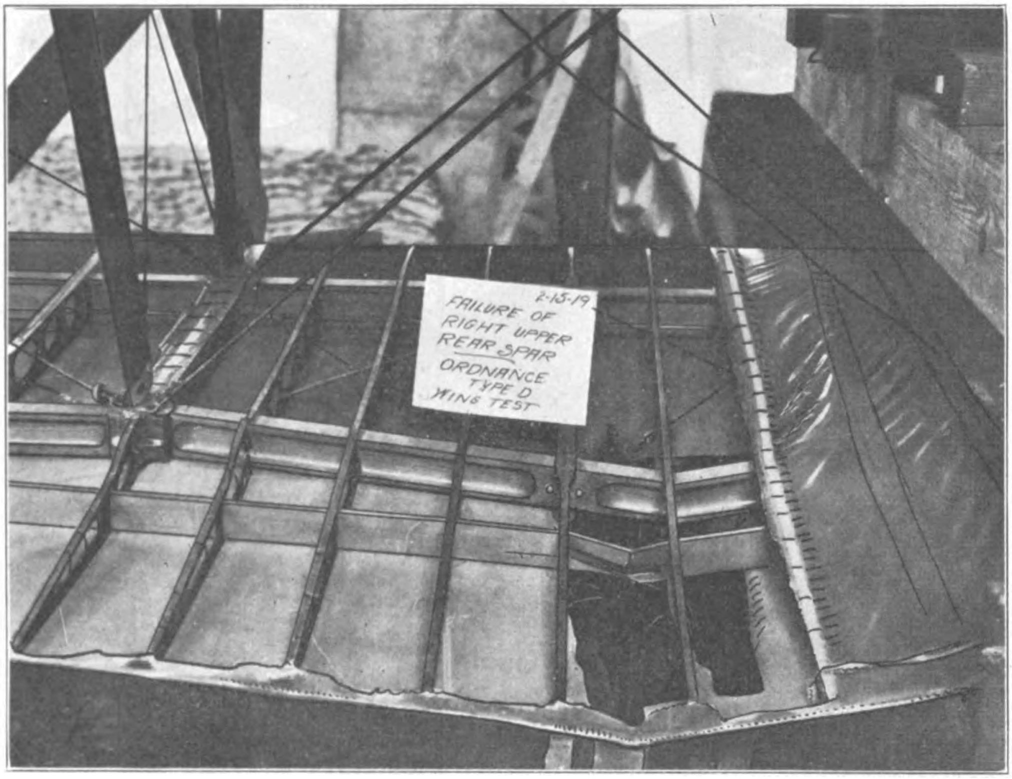

FIG. 7. Orenco-D.

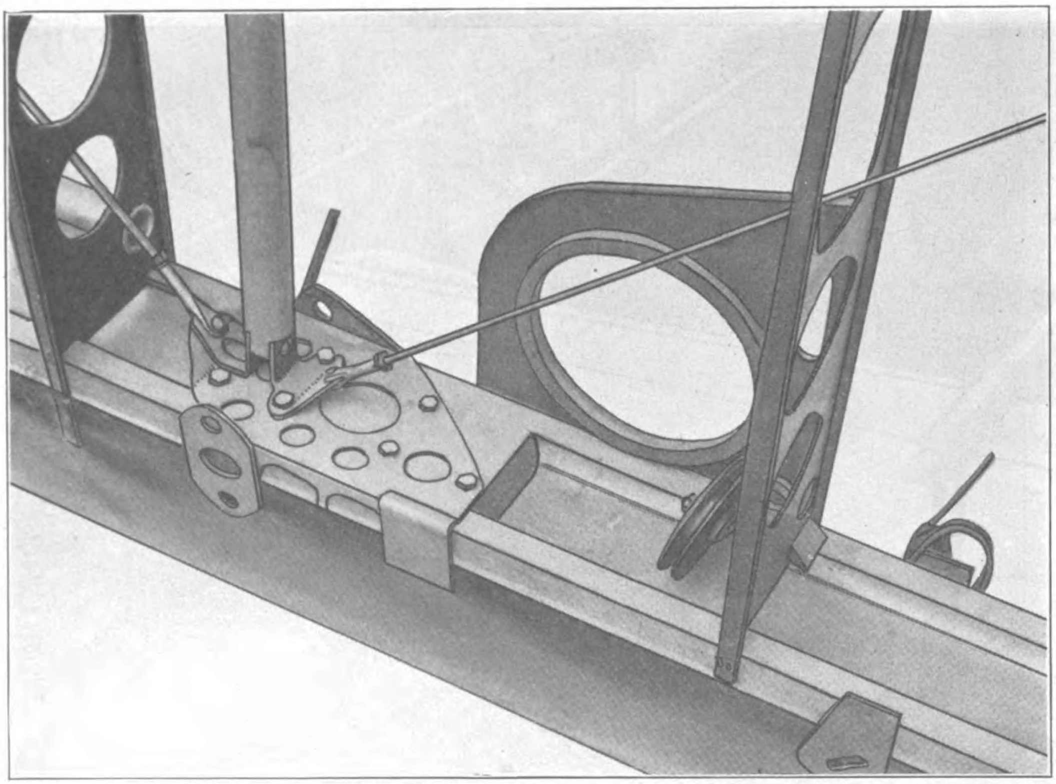

FIG. 8.—TW-1.

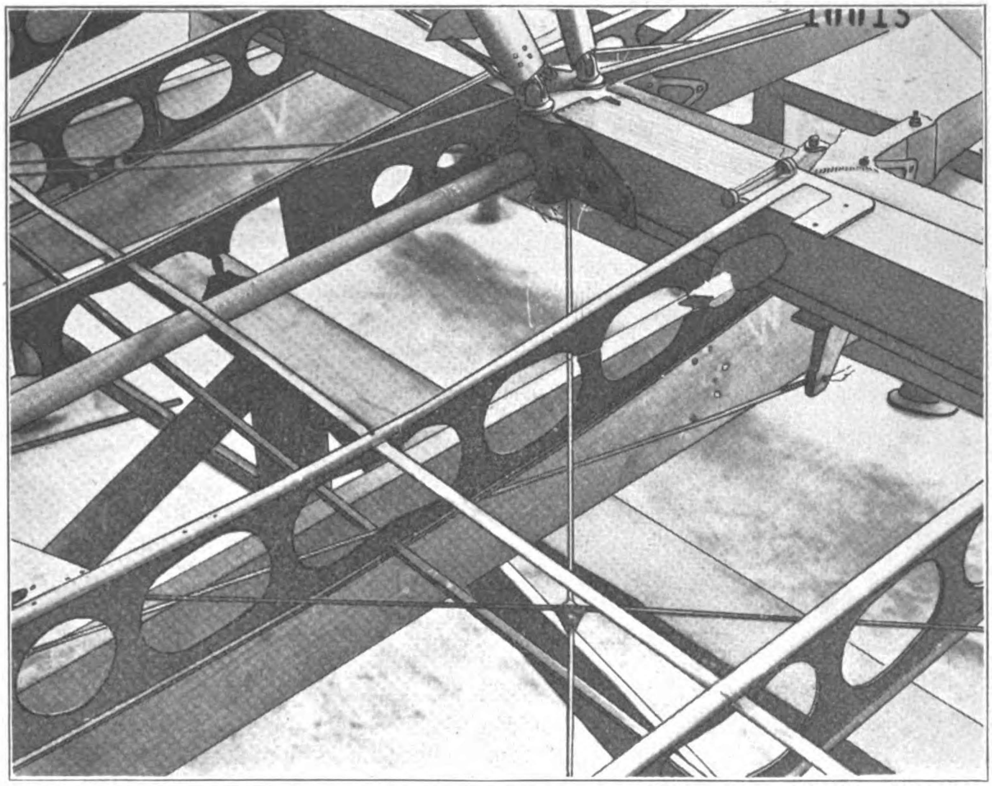

FIG. 9.—TW-1.

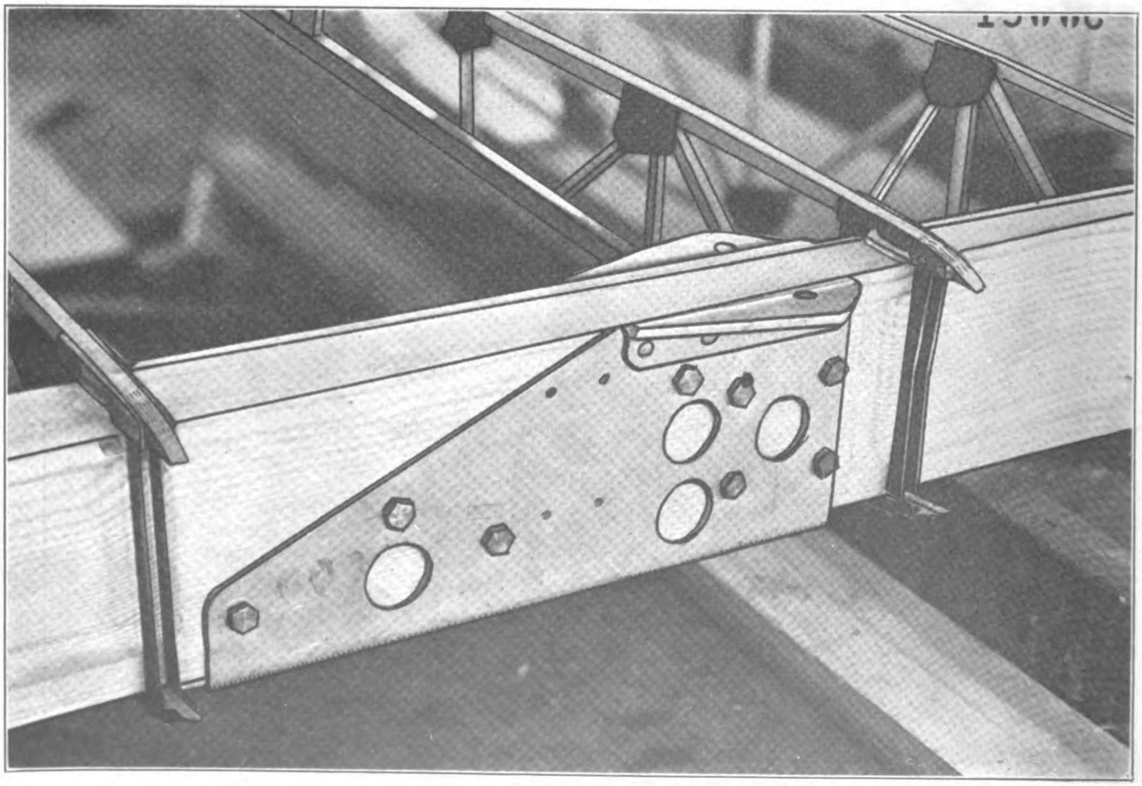

FIG. 10.—CO-2.

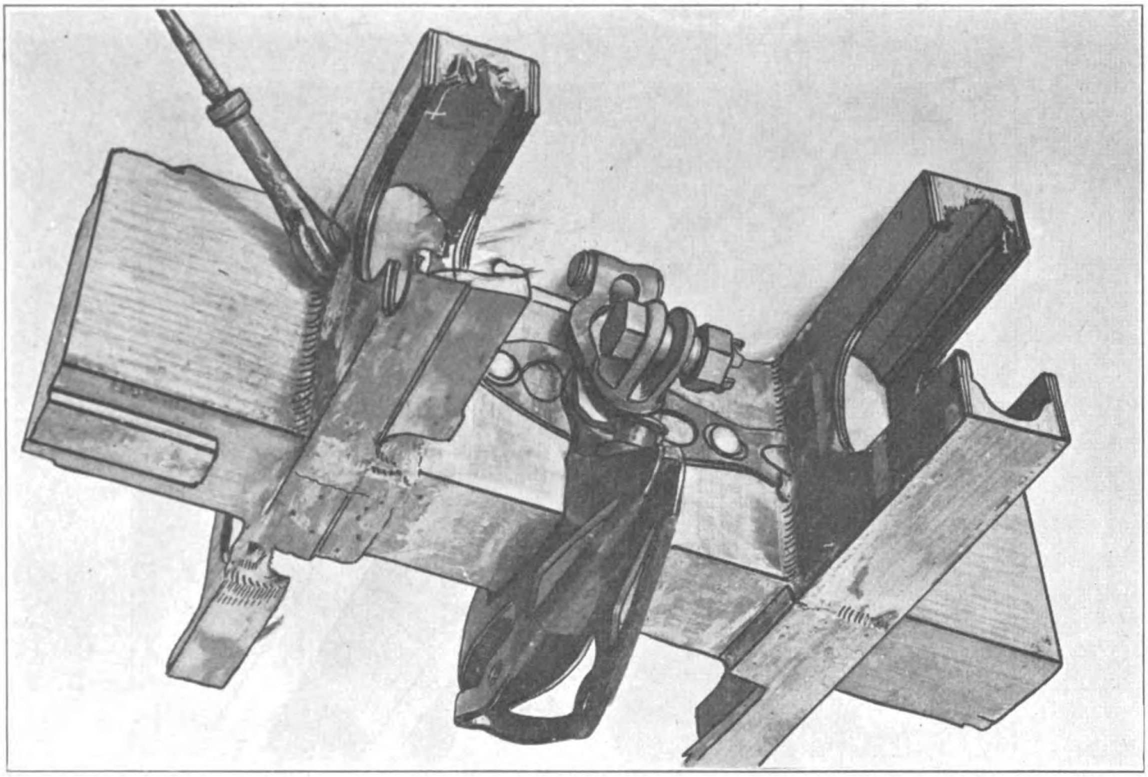

Fig. 11.—Thomas-Morse MB-6.

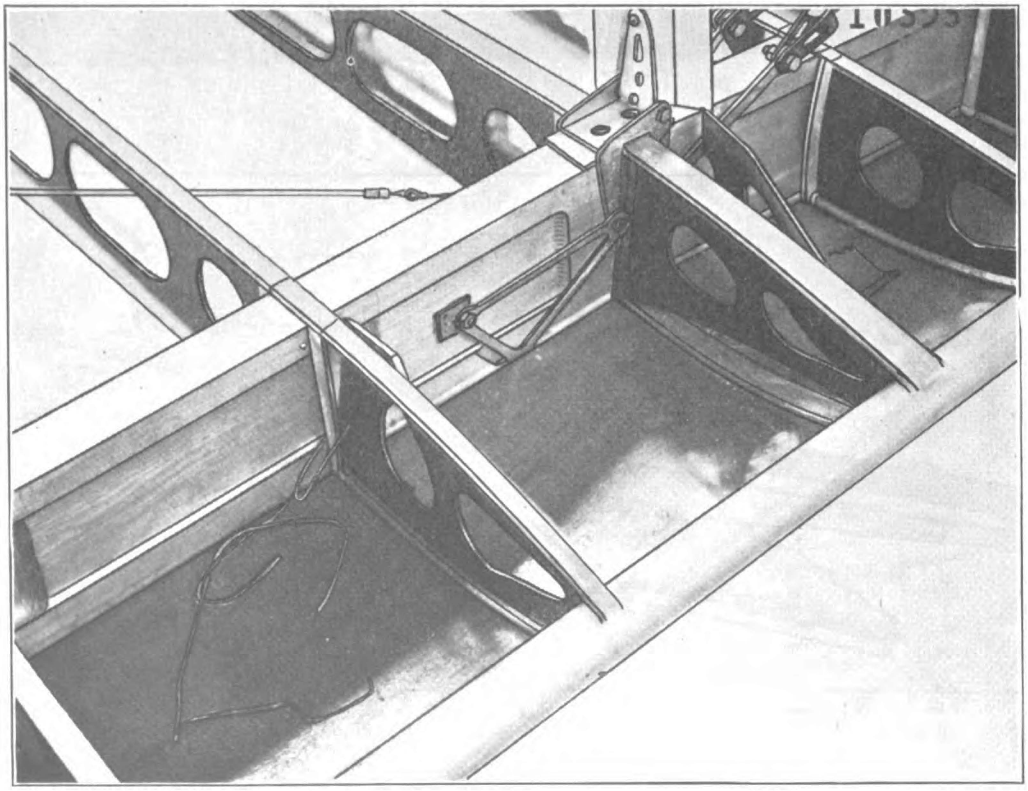

Fig. 12.—Orenco PW-3.

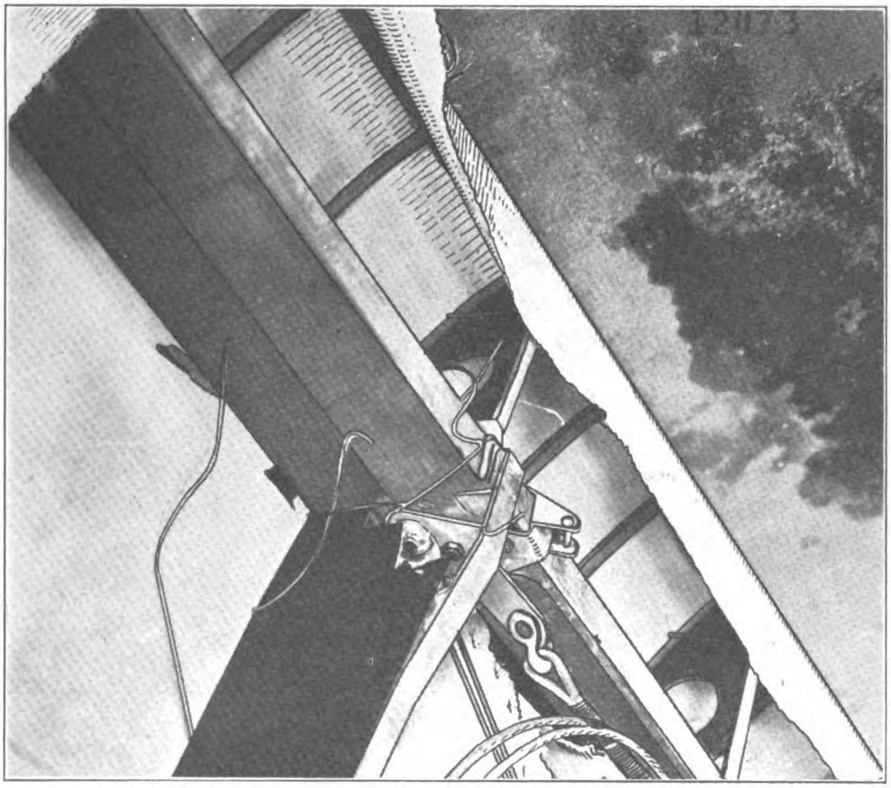

FIG. 13.—Dayton-Wright TA-3.

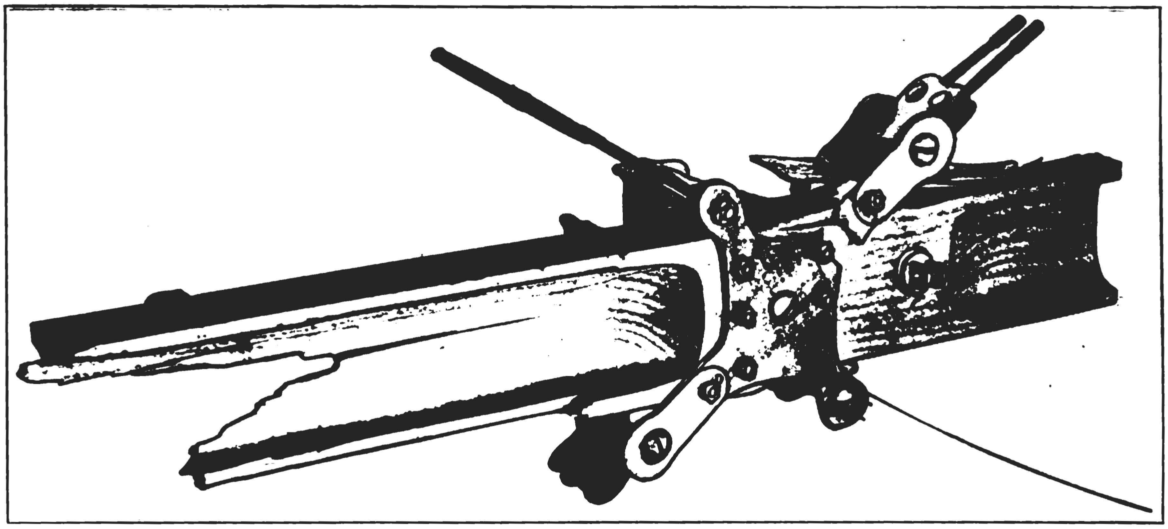

FIG. 14.—GA-1

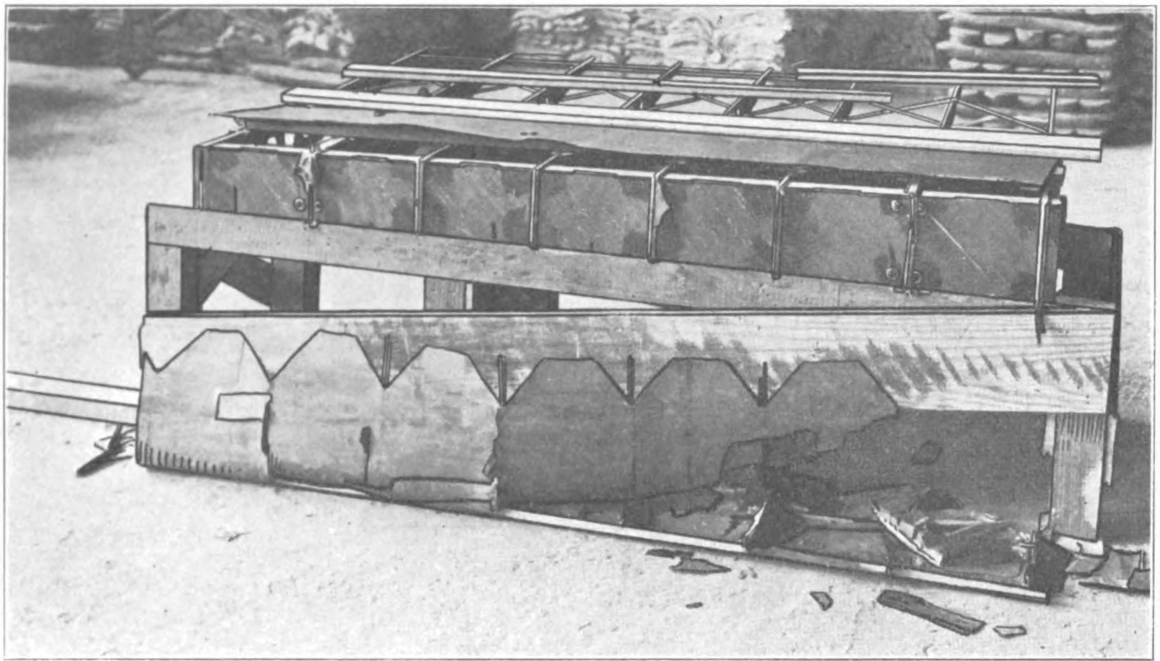

FIG. 15.—PW-1.

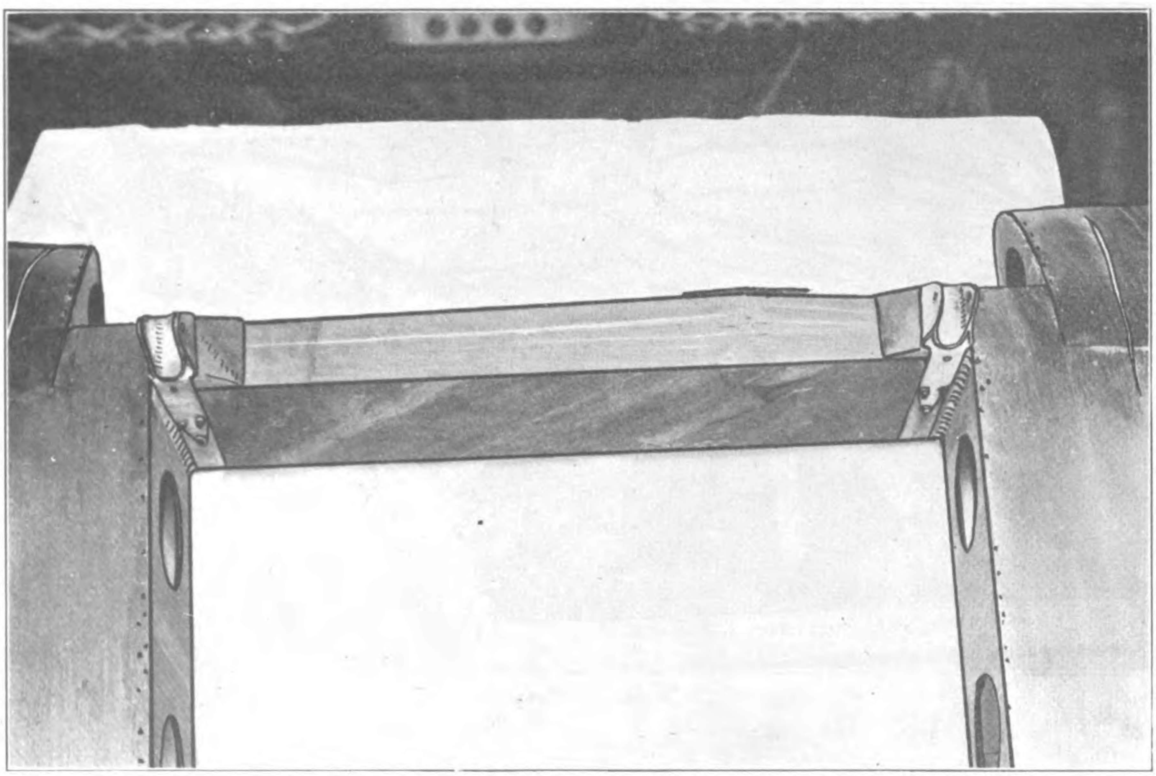

FIG. 16.—PW-1.

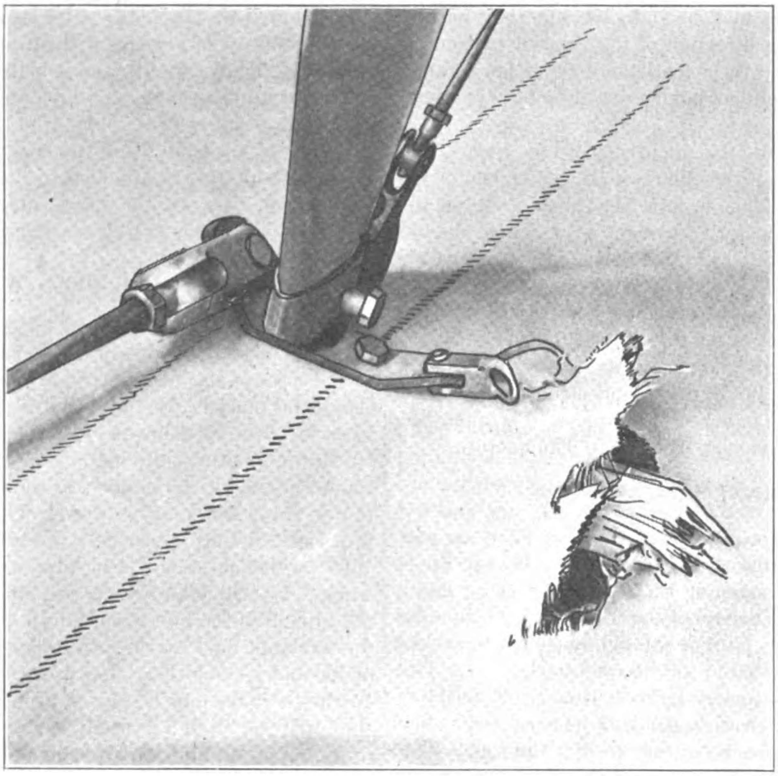

FIG. 1.—DH-9A.

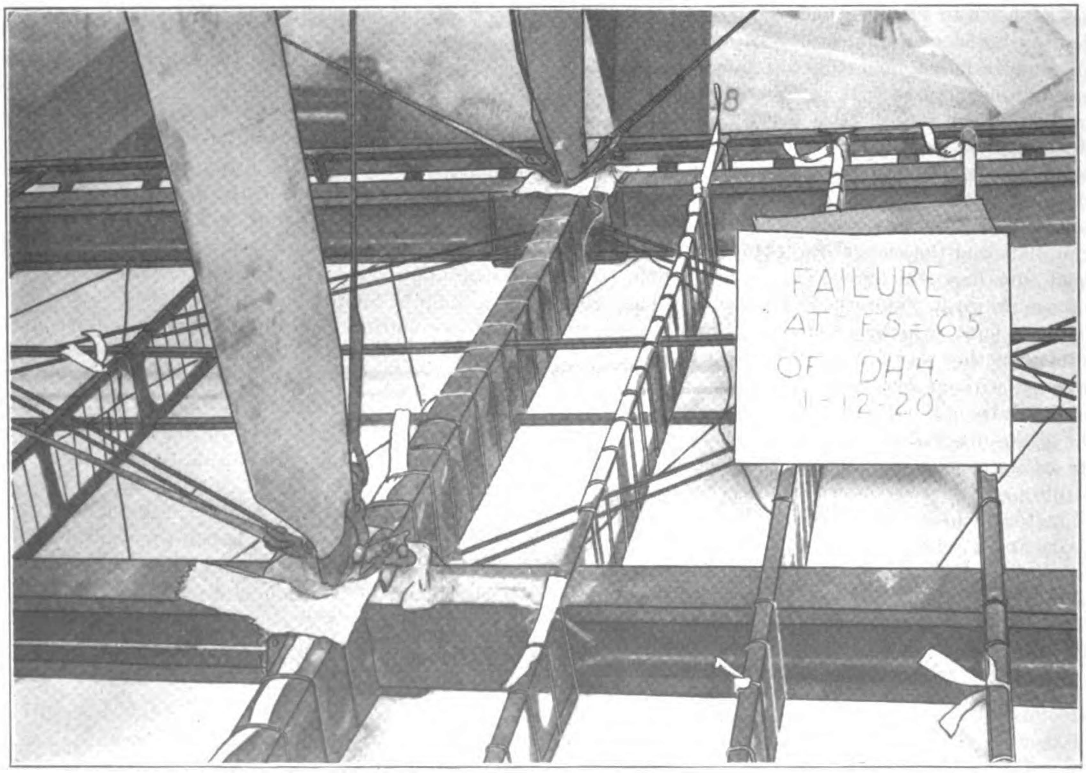

FIG. 2.—DH-4.

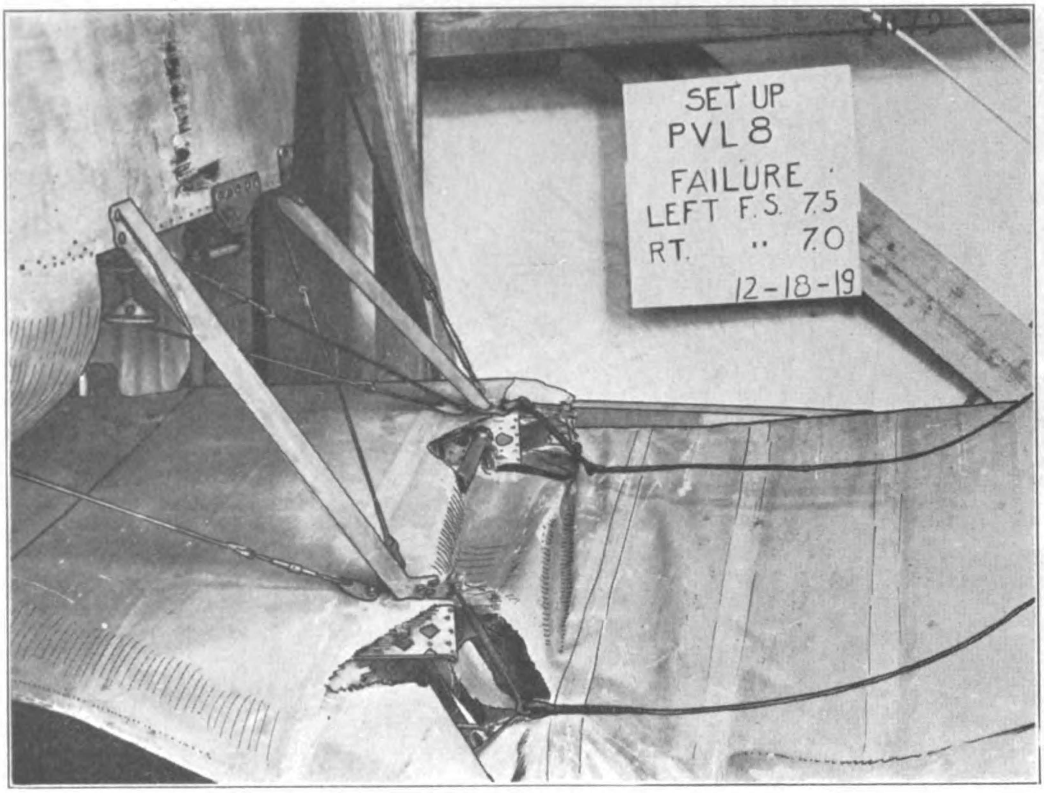

FIG. 3.—Pomilio FVL-8.

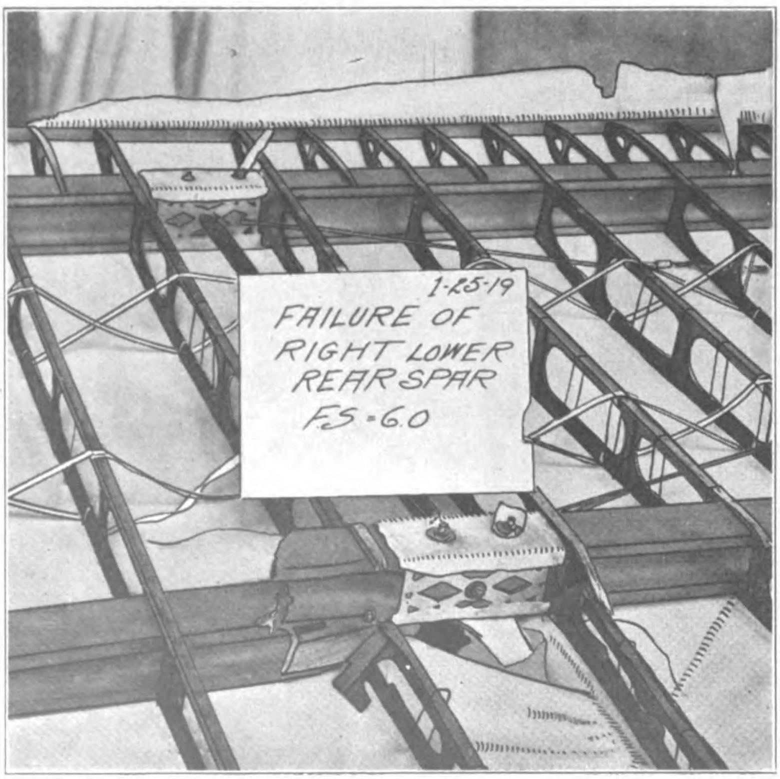

FIG. 4.—Pomilio BVL-12.

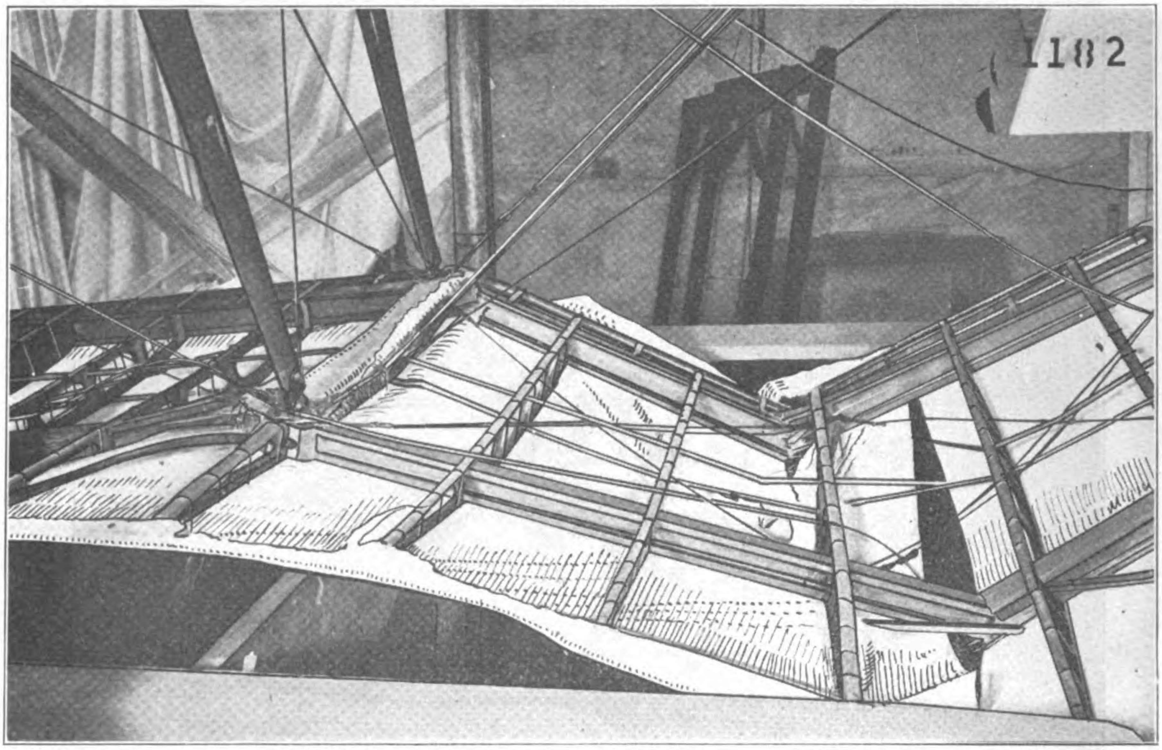

FIG. 5.—JN-4.

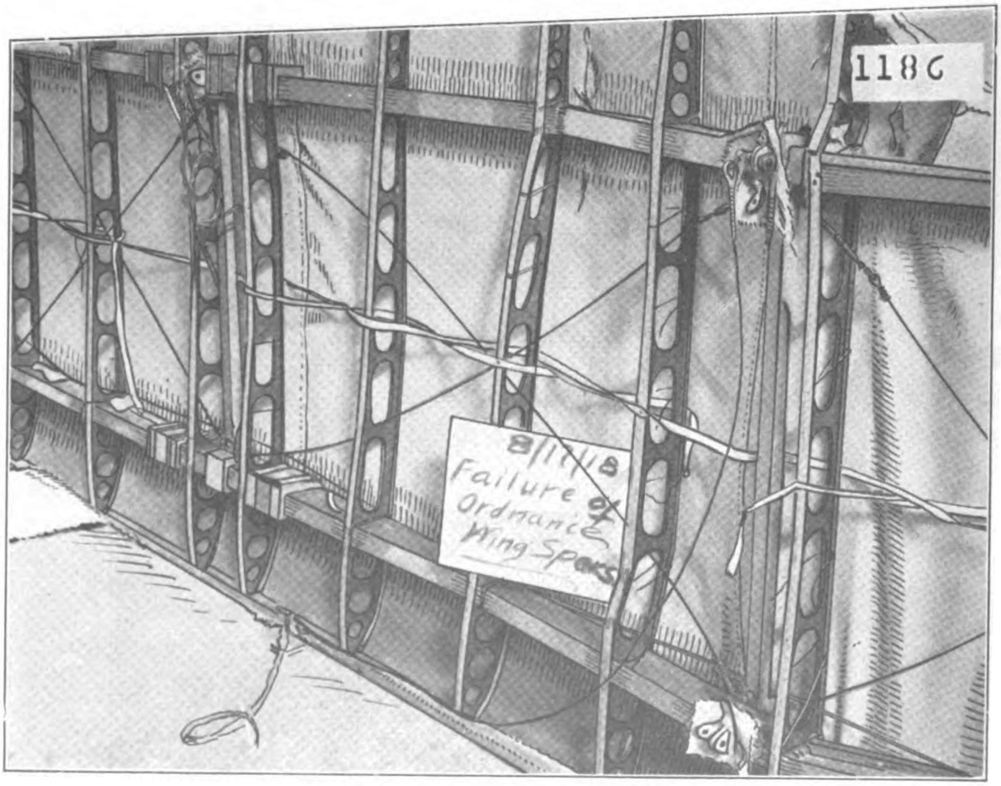

FIG. 6.—Orenco-C.

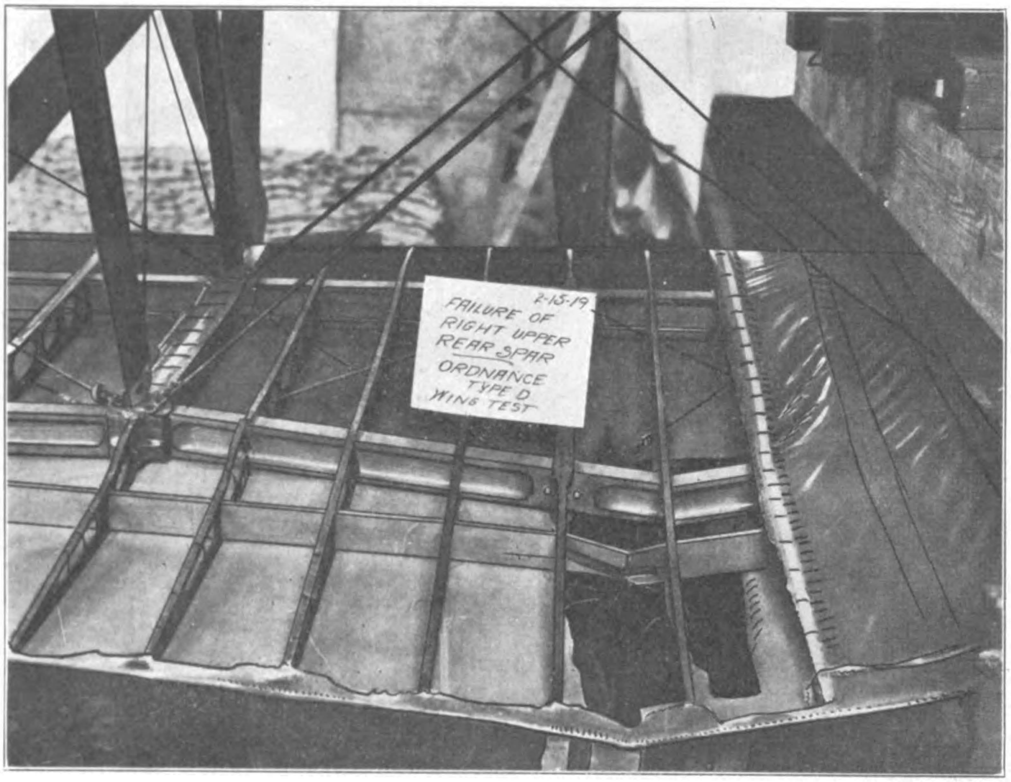

FIG. 7. Orenco-D.

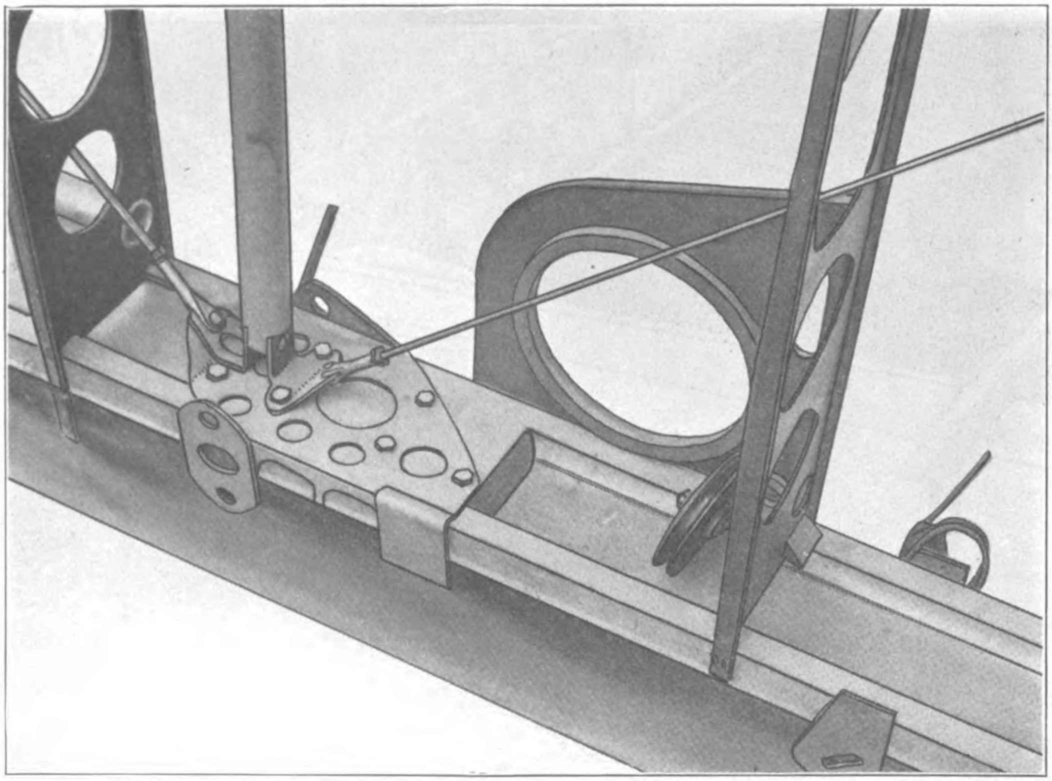

FIG. 8.—TW-1.